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ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

28 September 1945

SPMEA 727-2
Project No. T-5

1. PROJECT: No. T-5 - Test of Flameproofed Clothing, Fourth Partial Report, Subject: Test of Physiological Heat Load of Flameproofed Clothing.

a. Authority: Letter Headquarters Army Ground Forces, Washington, D.C., File 426 (9 Sept. 1945) GNRQT-11/40812, dated 9 Sept. 1945.

b. Purpose: To determine the physiological heat load induced by the wearing of flameproofed clothing.

2. DISCUSSION:

This report is a continuation of the studies on the influence of wearing flameproofed garments on the ability of men to work in hot environments. In the present tests, a new type of commercial flameproofing, "Banflame," was evaluated from the standpoint of heat load and general acceptability to troops.

3. CONCLUSIONS:

Herringbone twill uniforms made of cloth impregnated by the "Banflame" ADG process do not impose any greater load on acclimatized men than ordinary herringbone twill. Tests were performed at both hot dry (D.B. 120°F., W.B. 86°F., R.H. 26%) and hot humid (D.B. 88°F., W.B. 84°F., R.H. 85%) environments.

4. RECOMMENDATIONS:

That if field tests show the garment to have satisfactory durability, "Banflame" treated uniforms be considered suitable for issue.

APPROVED

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3 Incls.

- #1 - Appendix
- #2 - Tables 1-2
- #3 - Photographs 1 - 2

APPENDIX

1. SUBJECTS, EXPERIMENTAL CONDITIONS AND PROCEDURES:

This investigation was conducted in the laboratory hot room during August and September 1945. Twelve normal healthy soldiers were studied. Their ages ranged from 20 to 31 years (average 25); heights from 67 to 71 inches (average 69); weight from 135 to 190 pounds (average 155) and surface areas from 1.7 to 2.0 square meters (average 1.9).

The clothing was tested on men in two different environments which were representative of two types of hot climates.

- a. Hot dry - D.B. 120°F., W.B. 86°F., R.H. 26%
- b. Hot humid - D.B. 88°F., W.B. 84°F., R.H. 85%

Throughout the tests, the dry and wet bulb temperatures were measured every fifteen minutes with four motor-driven fan psychrometers at a level of four feet from the floor. The values rarely varied from the desired dry or wet bulb temperature by more than 1°F. The temperature of the walls, floor and ceiling was measured twice daily. In the 120°F environment the average of these measurements was 116 ± 1°F. and in the 88°F. environment the average was 87 ± 0.3°F.

A mildly turbulent air movement in all parts of the room resulted from the combination of hot air inflow from four anemostats in the ceiling and four 16-inch fans operating on the floor in the center of the room. Wind velocity was not measured but was essentially that produced by the movement of the men marching at 3 mph.

The men lived in barracks and were in the hot room five hours each day. The standard test work consisted of carrying a 20-pound pack and walking for four continuous hours at 2.9 mph around a 67-foot track in the hot room. This work rate was previously determined to be approximately 250 Calories per hour. Acclimatization to the heat was achieved by having the men march in the hot room for 25 days before the clothing was tested. Afternoon marches were taken to maintain physical fitness.

All water drunk during the test periods was 0.1% solution of sodium chloride. In the 120°F. environment the saline solution was kept at a temperature of 96°F; in the 88°F. environment, it was kept at 88°F.

"Banflame" is the trade name for a commercial flameproofing process^{*} formulated by Joseph Bancroft and Sons Company. It is applied to the uncut fabric. The specific treatment received by the cloth of the garments tested was the "Banflame ADG process" which imparts a launder resistant flameproofing which is satisfactory. The ADG process is an improvement over the former

^{*}Phosphate-urea mixture impregnation.

Bancroft processes which have been tested at other laboratories (1,2). The add-on is approximately 20%. Tests of tensile strength have revealed it to be somewhat impaired by this impregnation. The significance of this finding is being studied elsewhere. This clothing protects against flame alone and affords no gas-proofing. It is superior to other flameproofed garments tested in that the after-glow is negligible.

A Latin Square method of testing was used. Each of the men wore new unlaundered herringbone twill fatigues which had been treated with the "Banflame" flameproofing and new untreated herringbone twill uniforms once in each of the two environments. The clothing was always worn in the same manner; trouser legs tucked inside of the pulled up socks, jacket shirt tucked into the waist of the trousers, and top button of the jacket buttoned. This affords greatest protection against flame and since it reduces bellows action of clothing, these tests were carried out with the clothing imposing a maximum heat load at the given environment.

Upon arrival in the morning, the men remained in a room at 75° F. until individually called into the hot room 8-10 minutes before beginning to walk. Each man entered the hot room completely nude, urinated, dried off any sweat present and was weighed (within 10 grams). Simultaneously the jacket and trousers he was to wear (placed in the hot room 30-45 minutes earlier) were individually weighed (within 5 grams). The subject quickly dressed in these garments and stood erect 4 minutes during which the heart rate, rectal temperature and skin temperature were determined. He then began marching. During the walking period all water drunk, urine voided, and vomitus were carefully measured. At hourly intervals, the heart rate, rectal temperature and skin temperature were measured. He then stripped completely, urinated, dried off all of the sweat and was weighed. At the same time his removed clothing was weighed. Throughout the entire test, records were kept of the general appearance and reactions of the men.

The skin temperature of five areas of the body, three covered and two uncovered (chest, forearm, calf, cheek, palm) were determined with a radiometer. For clothed areas, the clothing was pushed aside just sufficiently to permit placing of the radiometer. Undue exposure of clothed areas was avoided. The skin temperatures of individual areas were integrated into an average skin temperature by the following weighting formula based on the original formula of Hardy: chest, 0.44; forearm, 0.14; calf, 0.23; cheek, 0.10; palm, 0.09. Henceforth the term skin temperature will refer to this weighted average skin temperature. Rectal temperatures were measured with calibrated rectal thermometers.

1. NRC Project MC, No. 27, July Progress Report, dated 10 August 1945.

2. Clothing, H.B.T., Effect of Flameproof Treatment on Climatic Research Laboratory, Provisional Reports I-IV, Test No. 155, dated 24 May, 4 June, 14 June, 1 August 1945.

2. RESULTS:

a. Heat Load at a High Dry Bulb Temperature:

D.B. 120°F., W.B. 86°F., R.H. 26%

This environment simulated that found in buttoned-up tanks operating in the summer at Camp Polk. The humidity is higher than that found in desert environments. The responses of the men working at this temperature show that impregnation imposed no added heat load on the men (Table 1).

b. Heat Load at a Lower Dry Bulb Temperature:

D.B. 88°F., W.B. 84°F., R.H. 85%

This environment simulates a typical tropical environment. Again the response of the men indicated that the impregnation imposed no added heat load (Table 2).

c. Physical Characteristics of the Clothing:

The "Banflame" clothing is almost indistinguishable from untreated herringbone twill in appearance (Photographs No. 1 and 2). Similar patterns in sweat uptake by the clothing occurred in both environments. The sweat uptake characteristics of the "Banflame" garment are very similar to those of the herringbone twill uniform.

The following table represents the average data on 12 men and their clothing.

TEST	CLOTHING	AVERAGE OF FOUR-HOUR SWEAT LOSS PER MAN (GRAMS)	UPTAKE OF SWEAT (GRAMS)	PERCENT OF TOTAL SWEAT IN GARMENT
D.B. 120° W.B. 86°	Flameproofed Uniform	6,923	862	12
	Herringbone Twill Uniform	7,035	883	13
D.B. 88° W.B. 84°	Flameproofed Uniform	3,601	1,004	28
	Herringbone Twill Uniform	3,300	1,037	31

d. Acceptability to Men:

Eleven of the twelve subjects stated that they preferred wearing the "Banflame" garments to wearing ordinary untreated herringbone twill uniforms. None of the men had any complaints concerning the garment. The subjective reactions of the men are of importance in view of the fact that in combat the men can wear or discard any item of clothing at will.

e. Flameproof Qualities:

Preliminary tests have indicated that herringbone twill fabrics impregnated by phosphate-urea mixtures not only have superior flameproof qualities, but are glowproof.* These qualities are maintained following laundering and immersion in sea water. As no information was available regarding the possible effect of large amounts of sweat in leaching out the impregnation, the garments used in this test were sent to the Climatic Research Laboratory of the Quartermaster General. It is understood that this organization will report on the flameproof and glowproof qualities of the worn clothing in the near future.

* The Flameproofing of Army Clothing. July Progress Report: 1945 N.R.C., Project CMC, No. 27. National Research Council Laboratories, Columbia University, N. Y.

TABLE I

The Physiologic Responses of Working Men Clothed in Flameproofed
and Standard Herringbone Twill

D.B. 120°F - A.B. 86°F - R.H. 26%

CLOTHING	NAME	RECTAL TEMPERATURE °F					PULSE RATE/Min.					SKIN TEMP. (AVG. W.G.) °F	WEIGHT LOSS (Sweat) Gm/2hr.
		Hours					Hours						
		0	1	2	3	4	0	1	2	3	4		
FLAMEPROOFED TWILL Bancroft ADG	Abb	98.8	100.5	100.5	100.6	100.9	90	123	111	102	111	96.6	2280
	Aur	98.6	100.9	100.9	101.1	100.7	102	117	126	120	117	97.1	1699
	DAG	98.0	100.0	100.1	100.0	100.1	87	117	120	114	117	96.4	1722
	Liv	98.3	100.3	100.1	100.0	99.9	87	102	120	117	120	96.8	1678
	Nam	98.6	100.9	101.1	101.3	101.4	96	120	117	123	129	96.4	1624
	Nar	97.9	100.4	100.5	99.9	100.3	105	114	117	120	120	96.9	1325
	Neb	98.6	100.0	100.5	100.5	100.6	99	123	126	120	108	96.4	1300
	Nol	98.0	100.4	100.3	100.3	100.3	102	114	114	108	111	97.4	1271
	Noo	97.7	100.6	100.6	100.6	100.3	96	123	120	111	117	98.3	1452
	Peo	98.2	100.7	100.8	100.5	100.3	105	117	114	114	126	97.4	1788
	Tho	98.3	101.0	100.7	100.6	100.4	99	120	105	111	117	97.6	1624
	Wes	98.4	100.0	100.1	100.1	100.0	102	117	108	114	114	96.8	1792
AVG.		98.3	100.5	100.5	100.5	100.4	98	117	117	115	117	97.0	1645
HERRINGBONE TWILL UNIFORM	Abb	98.3	100.1	100.4	100.3	100.4	87	108	117	108	105	96.8	2158
	Aur	98.8	100.2	100.4	100.2	100.2	102	117	108	108	117	97.3	1400
	DAG	98.0	100.3	100.5	100.3	100.0	99	114	126	117	114	96.3	1755
	Liv	97.9	99.7	99.6	99.7	99.6	96	120	117	114	123	97.1	1393
	Nam	99.1	101.5	101.4	101.6	101.7	99	120	120	114	123	97.0	1872
	Nar	98.0	100.6	100.6	100.5	100.2	99	120	117	114	120	96.9	1565
	Neb	99.1	100.4	100.6	101.1	101.1	102	111	117	114	114	97.9	1359
	Nol	98.3	100.2	100.0	99.9	99.8	102	111	117	114	117	98.4	1472
	Noo	98.1	100.9	100.7	100.7	100.6	102	123	123	126	117	97.4	1436
	Peo	98.1	100.4	100.1	100.0	100.0	96	120	117	117	114	97.6	2058
	Tho	98.6	100.4	100.4	100.4	100.4	96	111	120	120	123	96.6	1471
	Wes	98.6	100.3	100.0	100.1	99.9	114	120	126	123	120	97.2	1865
AVG.		98.4	100.4	100.4	100.4	100.3	99	117	120	117	118	97.1	1659

TABLE I

Incl. #2

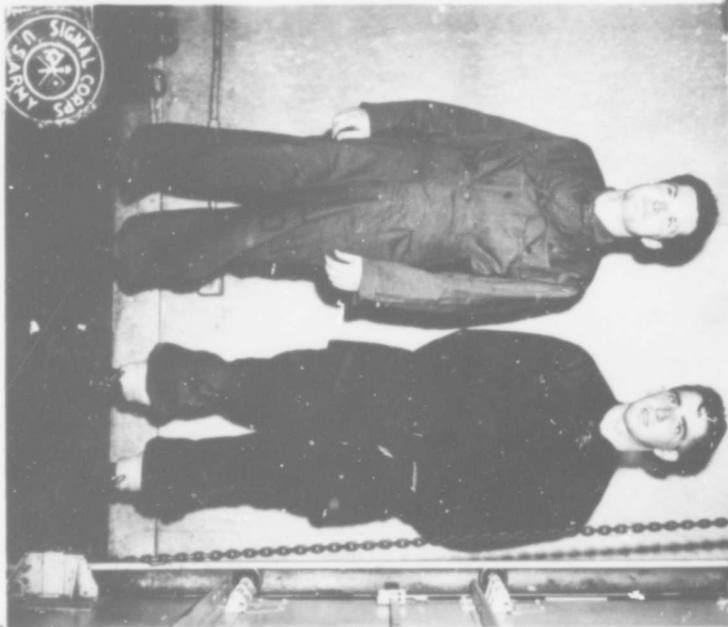
TABLE II
The Physiologic Responses of working Men Clothed in Flameproofed
and Standard Herringbone Twill

D.R. 88°F - W.E. 84°F - R.H. 85%

CLOTHING	NAME	RECTAL TEMPERATURE °F					PULSE RATE/100.					SKIN TEMP. (AVG. °F.)		WEIGHT LOSS (Sweat) Gm./hr.
		Hours					Hours					Int. 4 Hrs.		
		0	1	2	3	4	0	1	2	3	4			
FLAMEPROOFED TWILL Bancroft ADG	Abb	98.4	99.7	99.7	99.8	99.9	87	102	99	93	96	97.7	94.1	1321
	Aur	98.6	99.7	99.6	99.5	99.6	90	93	90	99	93	95.0	94.0	997
	Dlg	98.0	99.3	99.5	99.4	99.6	90	90	90	96	93	93.4	94.3	970
	Lrw	98.7	99.6	99.5	99.6	99.6	102	99	99	93	96	93.6	93.8	768
	Mcb	99.1	100.0	100.3	100.5	100.8	117	99	99	111	117	93.8	95.1	655
	Nam	98.7	100.5	100.5	100.6	100.6	117	120	117	117	114	94.7	94.7	761
	Nar	98.4	98.9	99.6	99.4	99.6	96	96	99	99	96	94.6	94.0	652
	Nol	98.4	99.6	99.6	99.9	100.0	93	99	93	84	84	95.2	94.5	670
	Noo	98.1	99.6	99.9	99.9	100.2	87	93	87	84	87	94.3	94.0	802
	Peb	98.1	99.5	99.6	99.6	99.7	102	102	99	102	108	93.2	94.7	639
	Tho	98.7	99.6	99.5	99.4	99.7	96	90	87	87	93	93.6	94.4	715
	Hes	98.3	99.5	99.7	99.7	99.7	105	108	105	93	93	94.1	93.0	898
AVG.	98.5	99.6	99.8	99.8	99.9	98	99	97	96	98	94.1	94.2	789	
HERRINGBONE TWILL UNIFORM	Abb	98.6	100.0	100.0	100.0	100.2	90	105	99	99	99	92.7	94.0	1513
	Aur	98.5	99.7	99.9	99.6	99.7	90	96	96	99	96	95.1	94.8	623
	Dlg	98.0	99.3	99.9	99.4	99.6	99	105	102	102	99	92.3	94.1	994
	Lrw	98.3	99.4	99.3	99.5	99.5	84	96	99	99	99	94.0	93.2	691
	Mcb	ILLNESS -												
	Nam	99.6	100.5	100.9	101.0	101.1	111	117	117	120	120	94.8	94.8	910
	Nar	98.6	99.7	99.9	100.1	99.9	105	105	96	96	99	95.1	94.0	705
	Nol	98.3	99.5	99.6	99.6	99.8	93	90	96	99	96	94.9	93.8	621
	Noo	97.6	100.1	100.2	100.1	100.0	87	99	102	99	99	94.2	94.8	810
	Peb	98.6	99.8	100.0	100.1	100.1	99	114	105	102	105	94.5	94.4	792
	Tho	99.1	99.8	99.5	99.7	99.8	96	102	93	93	93	93.8	94.3	762
	Hes	98.5	99.7	100.0	99.7	99.4	96	99	105	105	105	93.2	93.1	857
	AVG.	98.5	99.8	99.9	99.9	99.9	95	102	101	101	101	94.2	94.1	843

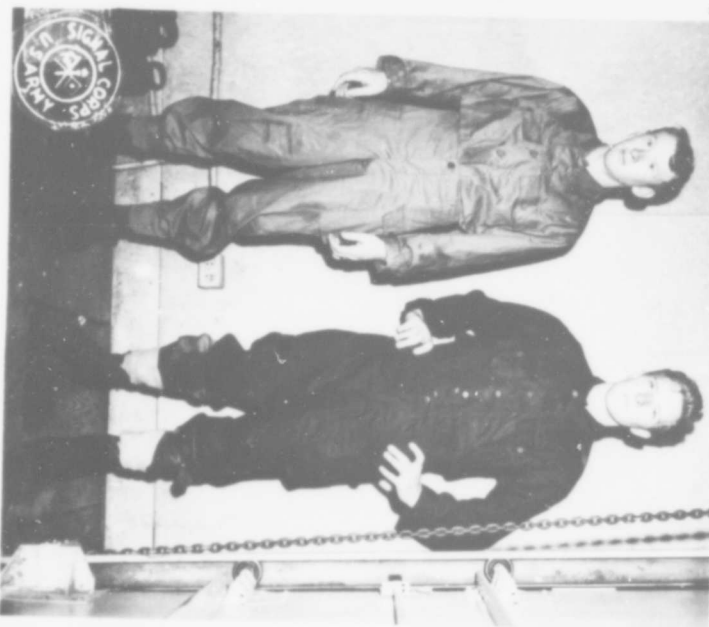
TABLE II

Incl. #2



Two men in laboratory will perform before (left) and after (right) four hours of wear at 120°F. - 80% RH. ARMORED MEDICAL RESEARCH LABORATORY FOR NIOSH ST. Photograph 21

Project No. T-5



Two men in laboratory will perform before (left) and after (right) four hours of wear at 120°F. - 80% RH. ARMORED MEDICAL RESEARCH LABORATORY FOR NIOSH ST. Photograph 22

Project No. T-5